Application Specific Chemical Information Microprocessor (ASCI µP)

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Award # N000149810848

LONG-TERM GOALS

The overall goal of this work involves the development of a self contained, integrated microfluidic chemical sensor using micromachining techniques. The integrated sensor targeted comprises a microanalytical segment, integrated detection electronics and associated telemetry functionality.

OBJECTIVES

The objectives of the scope of work encompassed multiple demonstrations: the architectural design of a microfluidic device as a reconfigurable chemical analyzer that utilizes on-chip reaction separation and either a photonic or an electrochemical detection strategy; the implementation of two different fluid flow pumping strategies; the use of hybrid packaging for electronic integration; progress on developing RF telemetry capability using micromechanical structures; and finally the design and manufacturing of a carrier package for electronics, fluid delivery and sample prep.

APPROACH

The approach taken was to first design then fabricate the custom microanalytical device and specify and design the final packaging and electronics. The most time intensive activity, testing of the capability of the microfluidic device in the lab and component integration, was left for the final portion of the project activity. The strategy of concurrent development of multiple subsystems was taken. The microfluidic chemical sensor has three main developments: laser induced fluorescence (LIF) detection; electrochemical detection; and wireless technology. In addition two modes of performance were approached; pumping by electroosmotic flow and high pressure pumping. The final quarter of the period of performance entailed the design and test of a carrier host for the chemical microprocessor. Further incorporation of the prototype microprocessor and subsequent testing was expected as follow-on work.

WORK COMPLETED

Laser induced Fluorescence Microchip

The LIF based microchip has progressed to the greatest extent. Figure 1a exhibits a microchip fabricated in glass and produced at the University of South Florida.

Report Documentation Page

Form Approved
OMB No. 0704-0188

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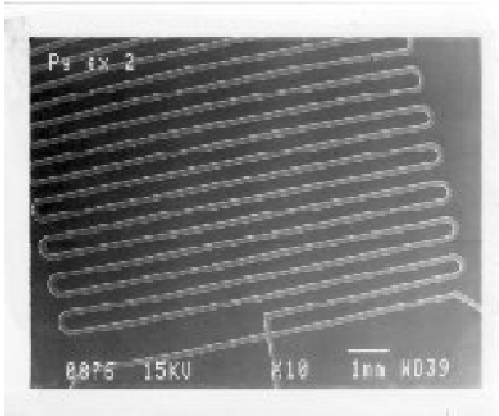
1. REPORT DATE **30 SEP 1999**	2. REPORT TYPE	3. DATES COVERED **00-00-1999 to 00-00-1999**
4. TITLE AND SUBTITLE **Application Specific Chemical Information Microprocessor (ASCI Î¼P)**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of South Florida,Department of Marine Science,140 Seventh Ave. South,St. Petersburg,FL,33701**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

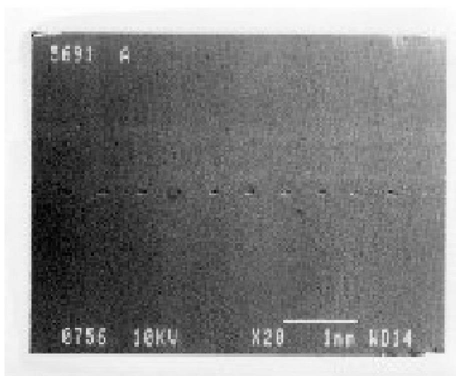
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT **unclassified**	b ABSTRACT **unclassified**	c THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18



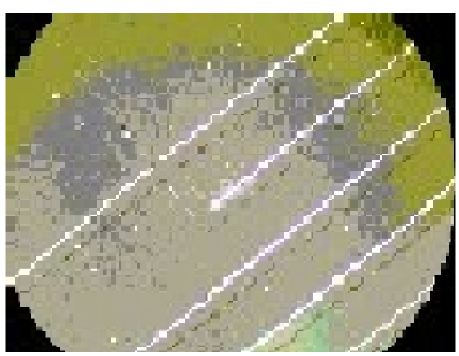
***1a*. SEM of channel which was pre-annealed and cleaned with a piranha etch**

The channels were fabricated in borosilicate glasses using standard lithographic and etching techniques. These channels, 100 microns wide, were etched to a depth of about 10 microns. A cover plate with holes drilled into the glass, needed for channel access, was thermally bonded onto the etched glass plate. The types of glasses used for this microfluidic channel device were Pyrex and Borofloat.



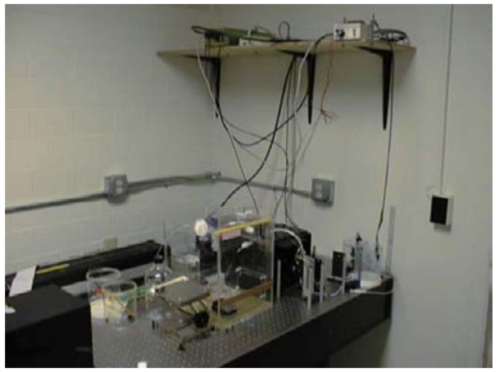
***1b. SEM of a cross section of channel showing bonded region*.**

We have made progress in manufacturing features in other substrates in order to prove the use of inexpensive materials as the basis for the microinstrument. We have etched channels in high resistivity silicon and using soft lithography created channels in polydimethylsiloxane polymer.



1C. Optical micrograph of 100 um line widths using soft lithography

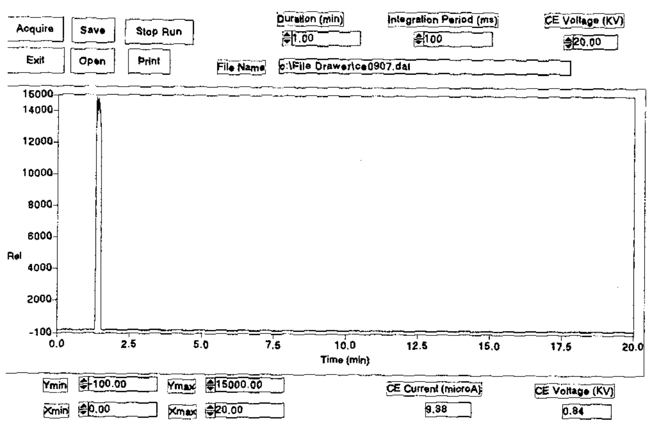
Progress has also been made on the tester setup for the laser induced fluroescence evaluation of the microchip. Figure 2 shows the tester layout including the He-Cd laser, and the high voltage chamber for the microchip. The tester uses a Labview virtual instrument PC-based interface.



2. CE-microchip tester system. (See proposal for schematic)

The tester footprint is being significantly (70%) reduced with the insertion of an acquired 5-inch blue laser diode module as a replacement for the He-Cd laser (the largest component of the optical layout). The blue-violet laser emits at 400nm at 5mW of power. Tagged chemicals that fluoresce using 400nm excitation light have been ordered.

We have used in the tester, a 12” length of bare fused silica of 50um id to align and optimize the optical and high voltage system. Figure 3 shows a hydrodynamic injection of a 10^{-5} um quinine sulfate solution. The voltage on the system was 20kv.



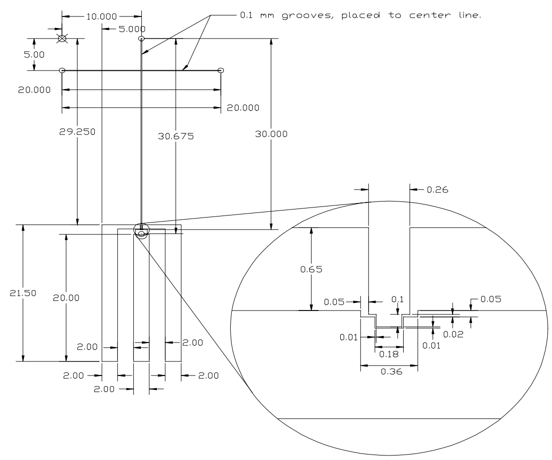
3. Hydrodynamic injection of 10^{-5} um quinine sulfate solution using LIF detection

The fused silica is in process of being replaced with the microchip version that duplicates the exact post column reaction process.

An added development that results from this project is that the glass CE chip has been design for a pediatric medical application based upon the request of the USF All Childrens Hospital Pediatric Dept. The same layout has potential utility as a red-tide brevetoxin sensor.

Electrochemical Detection Chip

We have made additional progress in the electrochemical detection mode of the CE device. First, we have modified the initial design seen in Figure 1 to incorporate a three-metal electrode detection arrangement at the outlet of the microchannel (Figure 4). We have a required electrochemical controller. The glass chips are currently being produced by a modified etch and thin film process.

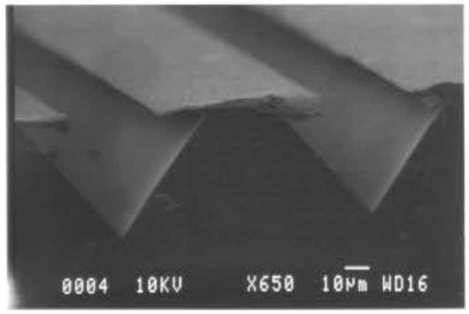


4. Electrochemical glass-chip design

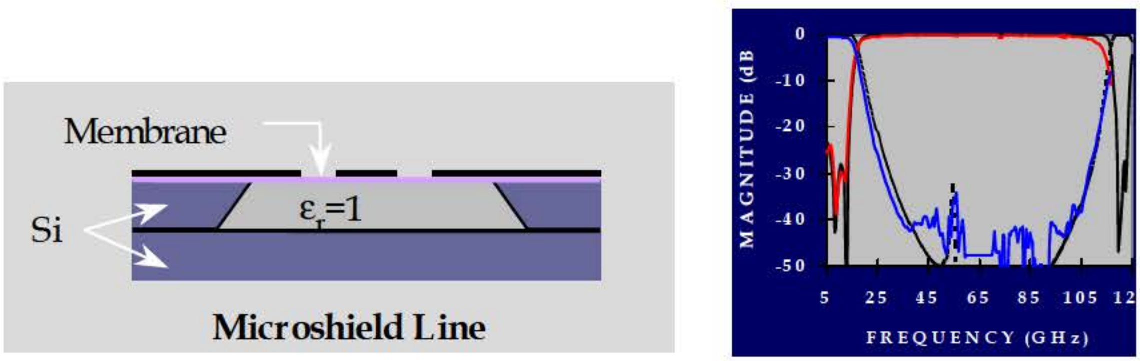
Second, we have developed an imprint process for microchannel fabrication in plastic, which provides easy fluid channel creation in polyether ether ketone (PEEK) which is a proven, highly chemically inert plastic with a 1000 psi pressure rating. The plastic chips will allow a Plastic Chip electrochemical detection via electrode insertion and placement. Furthermore the use of PEEK material has allowed us to solve the issue of practical interfacing of the chips to the outside world by the use of industry standard fittings. We have also collaborated with Dr. Jose Almirall at Florida International University and have accomplished the HPLC method development of explosives detection using UV detection as a first step toward the development of a chip- based explosive detector.

Wireless Technology

We have made advances in the area of wireless technology development. The more long term progress is toward the development of MEMS-based RF microstructures. Figure 5 shows the MEMS filter line structure fabricated and Fig. 6 schematic and performance data for a similar membrane topology.



5. Micromachined micro-shield filter line structure (schematic on right)

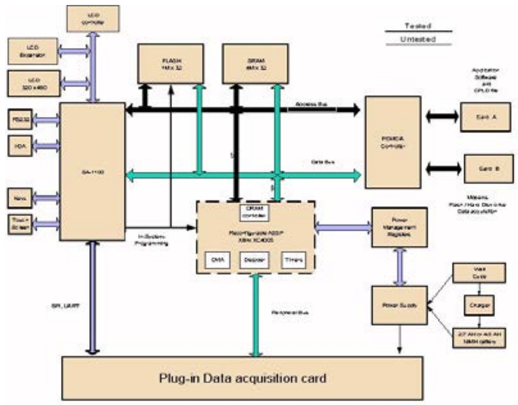


6. L: Suspended Membrane Schematic. R: Measured versus theory (blk)

Further progress of the micromechanical structures needed for a chip-level radio is being pursued separately. We have opted for the integration of a 2.4 Ghz Direct Sequence Spread Spectrum chip set from Intersil as the system architecture for cooperative telemetry capability in the integrated microinstrument.

System Electronics

The overall electronic carrier has been specified and fabricated through outsourcing to a portable design house. Figure 7 exhibits the block schematic of the electronic carrier package for the CE chip. The FPGA will allow the interface to the custom CE chip data acquisition circuitry.



7. Portable Electronic Carrier Schematic for support of CE chip DAQ

RESULTS

We have learned the techniques needed to fabricate microfluidic-based architectures in the most desireable analytical materials. We have established the base for LIF electrophoretic chip analysis and similarly for the electrochemcial detection. We have learned the large amount of effort needed to further the MEMS RF development. As expected, the optimizing of the test beds and method development have been the most time intensive efforts. Further advances in the testing, miniaturization and integration are the key to progress.

IMPACT/APPLICATIONS

This proof of technology demonstration has impact for both marine science and ocean systems applications as a design and development paradigm that can allow the creation of inexpensive microsensors. Ocean Observing Systems will benefit from the new manufacturing and technology approach.

TRANSITIONS

The work described here in concerted microsensor development is a new technological strategy for ocean instrumentation development. We expect this technology practice to emerge as the global ocean observing efforts emerge.

RELATED PROJECTS

An associated ONR funded project Phase Two Construction of and In-Situ Mass Spectrometer, is an extension of the microfluidic work presented here.

PATENTS

1.Fluid Controlled Flow Injection Apparatus. D.P.Fries (patent applied)
2. Accelerometer based on a (GMR) Giant Magnetoresistive Device, DP Fries (patent applied)